Desalination Technology Roadmap and Research Facility Development

Sponsors:

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Bureau of Reclamation

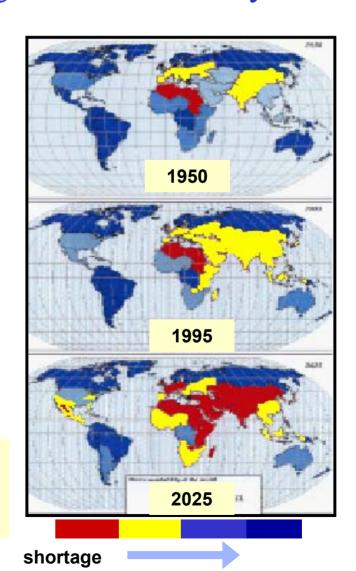
Project Managers Kevin Price, Thomas Jennings

Over half the world's population will face severe water shortage in the next 50 years.

- In 1990, poor water supply and sanitation was the 2nd leading cause of death and disability worldwide.
- Over 50% of world's major rivers are dry or heavily polluted.
- By 2025, 20% more fresh water will be needed for irrigation and 40% more for cities to maintain current per capita water levels.
- **NONTRADITIONAL** water resources will need to be used to address these shortages.

"Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations."

Fortune Magazine, May 15, 2000



Roadmap Development - Vision

By 2020, water purification and desalination technologies will contribute significantly to assuring a safe, sustainable, affordable, and adequate water supply for the Unites States.

Safe:

- Meet drinking water standards
- Agriculture and industry standards
- Security

Sustainable:

Water table decline can lead to salinity increase

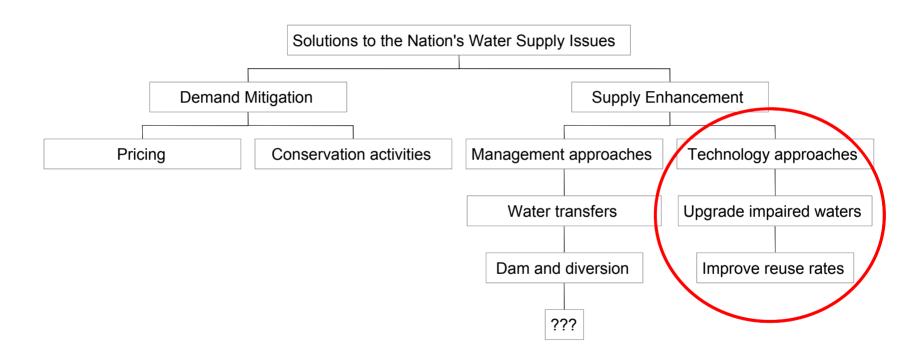
Affordable:

Future water cost comparable today's

Adequate:

- Local and regional availability
- Episodic shortages (droughts).

Hierarchy of the nation's water solution toolbox



Structure of the Roadmap Process



Case Studies a Basis for Needs

Urban Coastal



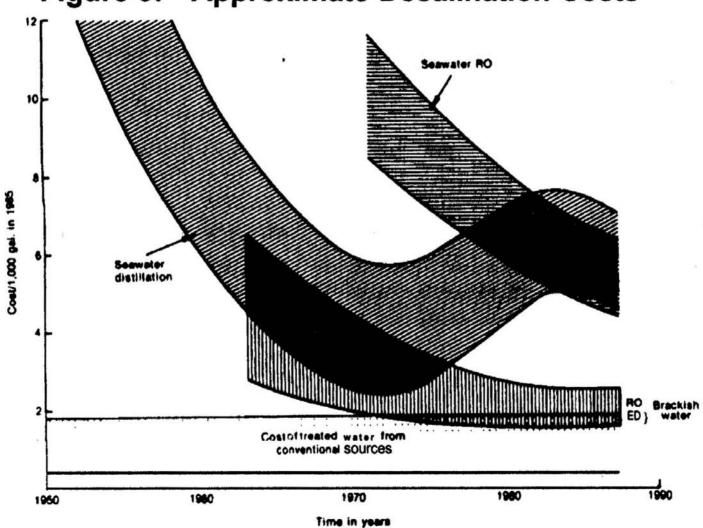


Inland Urban Inland Impaired Waters

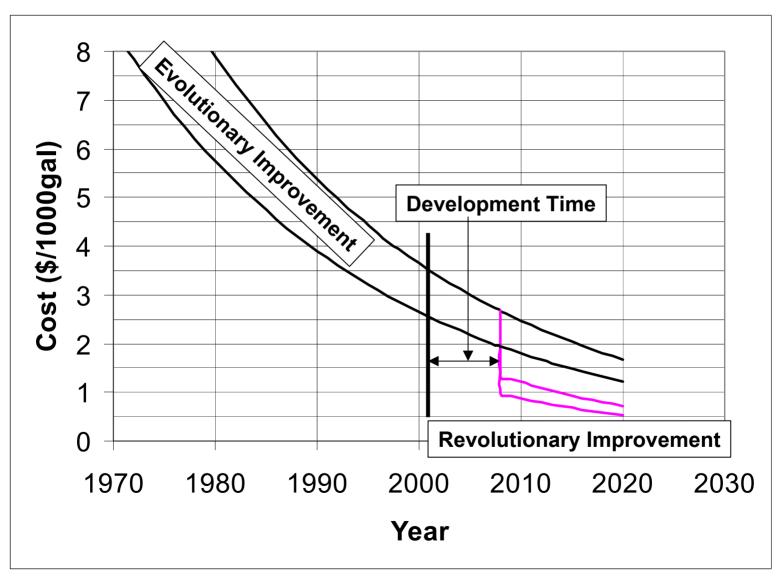
- Develop new sources
- Reduce costs
- Protect quality
- Reclaim waters
- Develop concentrate disposal

Historical Desalination Costs



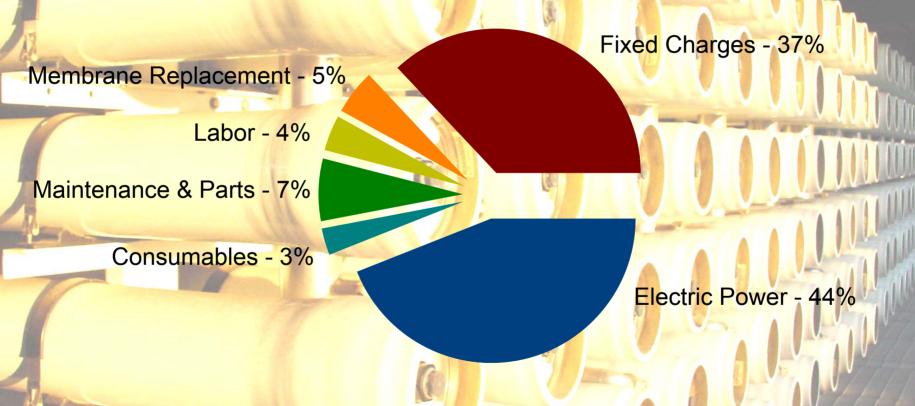


Effect of Evolutionary and Revolutionary Technologies



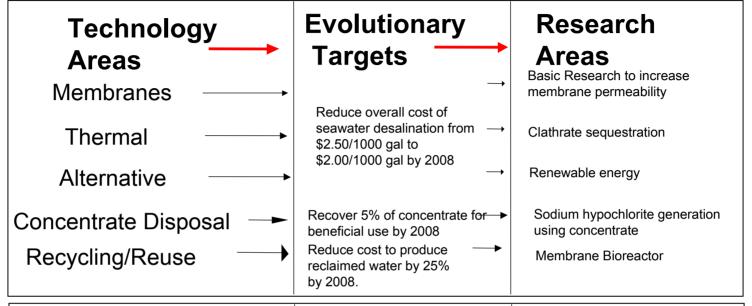
Evolutionary Approach Seawater RO – Opportunity for Energy and Pretreat Savings

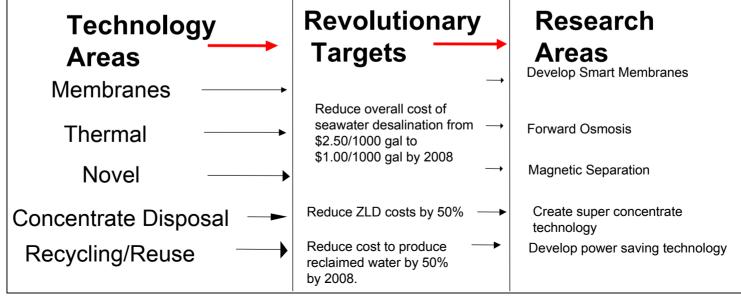
R. Semiat, Water International, Vol. 25, 54, (2000).



Pretreatment can be up to 30% of Total Operating Costs
K.S. Speigler and Y.M. El-Sayed, <u>A Desalination Primer</u>, Balaban Desalination Publications,
Santa Maria Imbaro, Italy (1994).

NEEDS → Objectives (Reduce Costs)





Revolutionary Approach

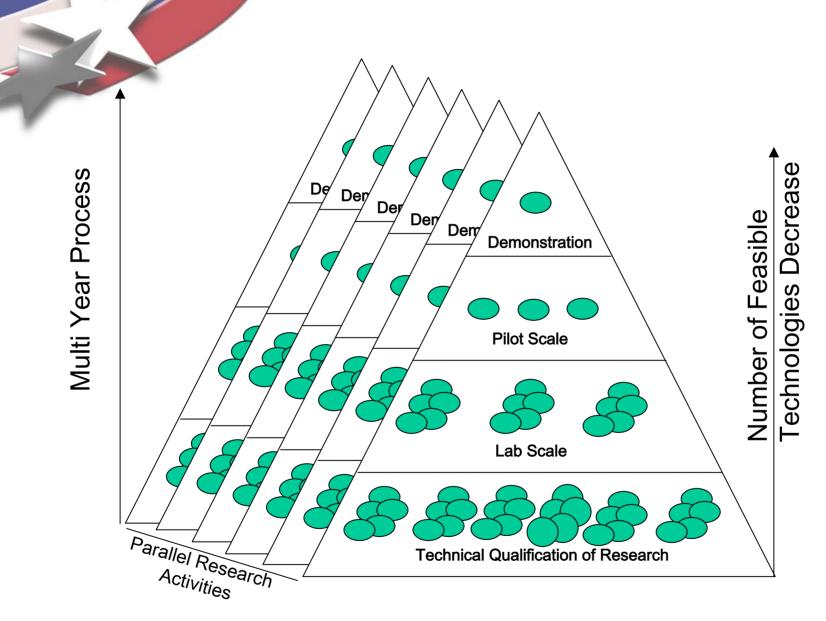
Series of Screens

Technical qualification of research – M&E Balances

Lab Scale Evaluations

Pilot Scale Evaluations

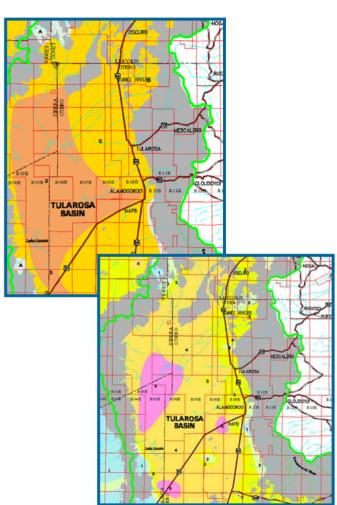
Demonstrations



In order to have demonstration scale experiments for the National Desal Centers program, there must be a major program to develop worthy candidate revolutionary technologies. Without this program, only evolutionary research will be available for testing.

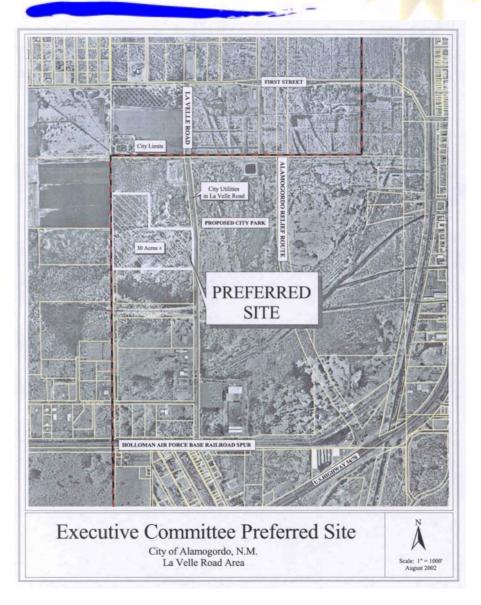
Study Objectives

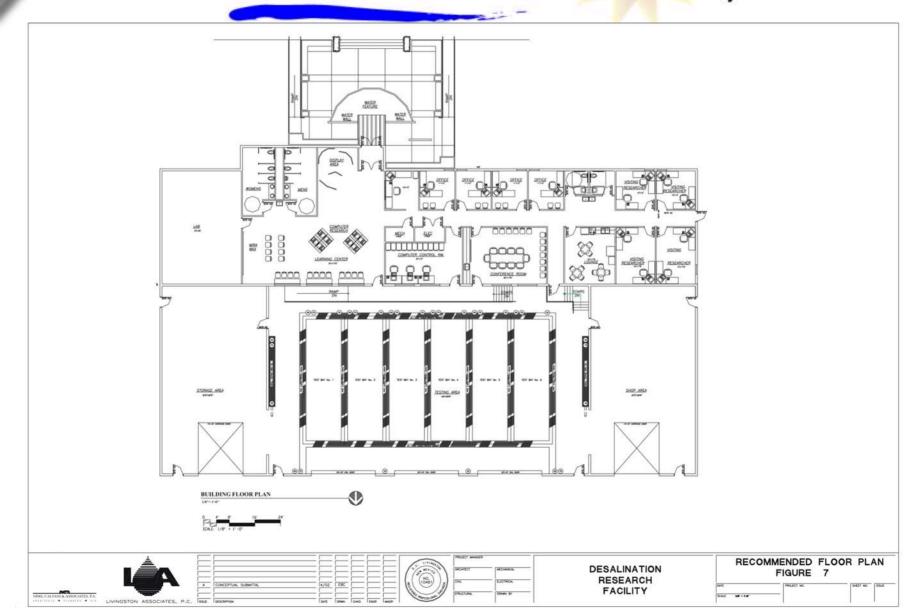
- The BOR and Sandia received congressional funding in FY02 to:
 - Identify desalination research opportunities for a Tularosa Basin facility
 - Identify a regional, national, and international role that would complement other "national water research centers"
- Develop a preliminary facility design and operation and management plans
- Complete draft study by July 2002
- Develop facility design/build plan for FY03 start of construction



Design Highlights

- 3 primary site locations identified with easy access, good visibility, water availability
- 20-30 acre sites with areas for concentrate reuse and beneficial use research, renewable energy desalination research, and ~13,000 square foot desalination research facility
- Desalination facility: 6 test bays for pilot system testing at 30 gpm, control room, water lab, research offices, resource/education room, conference room, operations viewing and tour areas, passive solar building
- Shop and chemical storage areas and exterior pads for large scale and renewable energy applications





NEED: Reduce Production Cost of Water

NEAR-TERM

Research Areas

- Computational Modeling
 - Develop system-optimization model for membrane-based facilities
 - Investigate parameter sensitivities in computational models
 - Develop computational modeling capabilities for distillation, evaporation, and vapor compression plants
- Hybrid and combined systems
 - Cogeneration (water and power from the same plant)
 - Membrane and thermal combinations
 - Solar ponds (combined concentrate disposal/energy production)
 - Combined driving (magnetic- and pressuredriven movement of water through membranes)
- Low-grade heat (using waste heat for thermal desalination)
- Operational Research
 - Develop improved scale inhibitors
 - Develop/evaluate non-standard RO train configurations

Near-term CSRs

- ↓ capital costs by 20%
- ↓ operating costs by 20%
- ↓ membrane train costs by 10%
- ↓ pretreatment costs by 25% for reclaimed waters

Mid/long-term CSRs

- ↓ capital costs by 50%
- ↓ operating costs by 50%

MID/LONG-TERM

Research Areas

- Materials Research
 - Replacement for titanium components
 - Corrosion-resistant composites for pumps/piping
- Net zero-energy desal plant (energy-self-contained)
- Automation (lower labor costs)
 - Remote security monitors
- · Economic and process modeling
 - Predict desal costs vs. cost of water from other sources
- Membrane Research
 - Develop completely fouling-resistant membranes
 - Develop completely oxidant-resistant membranes
 - Develop membranes that operate in a range of pHs (reduce the need for mechanical/chemical cleaning)

NEED: Increase Production Efficiency

(throughput, component lifetime, quality)

NEAR-TERM

Research Areas

- Basic Research
 - Develop mechanistic/fundamental knowledge of membrane functions
- · Water Quality
 - · Develop better surrogates for trace organics
 - Improve removal of pharmaceuticals/ endocrine disruptors
- Throughput
 - Develop materials that can (increase the membrane module operational envelope
 - · Improve permeability/minimize resistance
 - Develop membrane fouling indicators
- Novel, efficient processes
 - Ultrasonic/Supersonic
 - Capacitance
 - · Ion sorption
 - · Sodium pump/biomimetic
 - Magnetics
- · Enhanced thermal desal processes
 - · Water harvesting from air
 - · Enhanced evaporation
 - · Forward osmosis

Near-term CSRs

- ↑ energy efficiency by 20%
- Remove 60% of synthetic compounds
- ↑ throughput rates by 10%
- Sense water quality and contaminant removal
- Achieve on-demand contaminant removal

Mid-long-term CSRs

- ↑ energy efficiency by 50%
- •

MID/LONG-TERM

Research Areas

- · High slurry filtration with electro-chemistry
- Ion Sorption/Zeolite crystallization
- · Biomemetic systems
- · Advanced membranes/separation
 - · Non-traditional materials
 - Biologic membranes/separation systems
 - · Ion selective membranes
- · Pre-treatment research
 - · Magnetic/ionic methods to attract particulates/microbes
- Controls
 - 'Smart' controls that adjust pretreatment/membranes in response to feed water quality fluctuations
- Sensors
 - on-line viral analyzer
 - · In-situ sensors to detect biofilms, fouling, scale formation

~ 2003 ~ 2008 ~ 2012 ~ 2020 Year

NEED: Address Concentrate Disposal Issues

NEAR-TERM

Research Areas

- · Beneficial use
 - Solar ponds for energy and concentrate management
 - Sodium hypochlorite generation using concentrate
- Concentrate treatment
 - Reduce concentrations of fluorides, radionuclides, pesticides, metals
 - · Bioengineering contaminant removal
 - Develop a "super concentrate" technology
- Engineered ecology/bioengineering
 - Engineer disposal so that it does not harm ecosystems, and if possible benefits them
 - Natural analogs to current treatment/Constructed wetlands
- Evaporation
 - Enhanced mechanisms to encourage or enhance evaporation
 - Health or environmental impacts of enhanced evaporation
- Discharge
- Develop models of dispersion, including tidal influence where appropriate
- Shallow receiving water diffuser research

Near-term CSRs

- Recover 5% of concentrate for beneficial use
- \(\psi \) reject percentage by 17% (50% for brackish water)
- Maintain cost of concentrate disposal over time
- volume of concentrate disposed by 500/2
- Maintain environmental compatibili

Mid/long-term CSRs

- Recover 20% of concentrate for beneficial use
- ↓ reject percentage by 85% (for brackish water)

MID/LONG-TERM

Research Areas

- · Beneficial use
 - Develop bugs that solve salt problem and produce a useful product
 - Solar ponds
 - · Identify industries that need high salinity water
- Toxicity assessment and response
 - Research in reduction of toxicity of concentrate
 - Differentiation of the causes of biotoxicity and concentrate treatment methods
- · Innovative concentrate management
 - · Decentralized (Point of Use) Treatment and recycling
 - Engineered ecologies/Creation of a sustainable saline ecosystem
- Treatment
 - Remove specific contaminants/Reduce costs of zero level discharge
- Creation avoidance
 - Develop treatment processes that do not produce concentrate

 ~ 2003 ~ 2012 ~ 2020

NEED: Increase Reclamation and Reuse of Water

NEAR-TERM

Research Areas

- · Public health issues
 - Structure/activity relationships (NDMA, other)
 - Methods of removing pharmaceuticals/ endocrine disruptors
- Ensuring quality
 - · Develop better surrogates for trace organics
 - · Decrease the cost of sampling
 - Develop next-generation sensors
 - · Investigate 'blending' issues
- Treatment technologies
 - Research membrane bioreactors
 - Investigate advanced filtration approaches
 - Develop biological (disinfectant) coatings
 - Examine challenges presented by effluentdominated streams in the West
- Storage/post-treatment uses
 - Constructed wetlands
 - Generate models to predict migration through/recovery from aquifers

Near-term CSRs

- cost of use of reclaimed waters by 25%
- † stability of reclaimed waters over time (reduce time-induced degradation)
- \(^\) volume of water available for aquifer recharge
- \tag{knowledge base to allow more aquifer storage}

Mid/long-term CSRs

MID/LONG-TERM

Research Areas

- Economics
 - Document the economics of water reuse for various applications
- Controls
 - Develop automated sensors/controls that adjust pretreatment/membranes in response to feed water quality fluctuations
- Treatment
 - Optimize filter design
 - Develop enhanced membrane bioreactor technology
- Quality
 - Develop set of organic chemical surrogates acceptable to public for potable reuse/ develop a sensor for the surrogate organic
 - Generate better scientific underpinnings for dealing with microbial contaminants
- · Protection of human health
 - Develop the QSAR to predict removal or emerging contaminants

~ 2003 ~ 2008 ~ 2012 ~ 2020